

# A CRITICAL ANALYSIS OF THE MOVEMENTS OF THE SHOULDER-JOINT

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Although much has been written concerning the morphology of the shoulder-joint of the various Tetrapods, as well as the nature of the movements permitted, the writer is of the opinion that certain terms relative to the movements of this joint in man should be clarified. It is generally agreed that, although considerable variation exists in the range of movements, in Mammals the humerus may undergo flexion, extension, abduction, adduction, medial (internal) and lateral (external) rotation round its longitudinal axis and a combination of these movements called circumduction. The term abduction with reference to the shoulder-joint is invariably used to indicate elevation of the humerus laterad and adduction to signify depression of the humerus from the latter position toward the side (mediad).

However, as regards the use of the terms flexion and extension as applied to the shoulder-joint considerable discrepancy exists between the various aspects of anatomy. It is with the interpretation and employment of these terms that the present paper is concerned. The term flexion in general is usually defined, or conceived of at least, as being that movement at a joint whereby the angle between corresponding surfaces of the apposed bones is decreased whereas extension is considered to be that movement in which this angle is increased. The connotation of these terms is evident in the case of angular joints such as the elbow and knee. However, in the case of multiaxial joints, and more especially the shoulder-joint, these movements are rather difficult to classify on the basis of this criterion.

In textbooks of Comparative and Veterinary Gross Anatomy flexion of the quadruped shoulder-joint is interpreted as swinging backward (caudad) of the humerus and extension as swinging forward (craniad) of the humerus. The criterion employed for this classification in these texts is the displacement of the dorsal surface of the humerus with respect to the caudal border

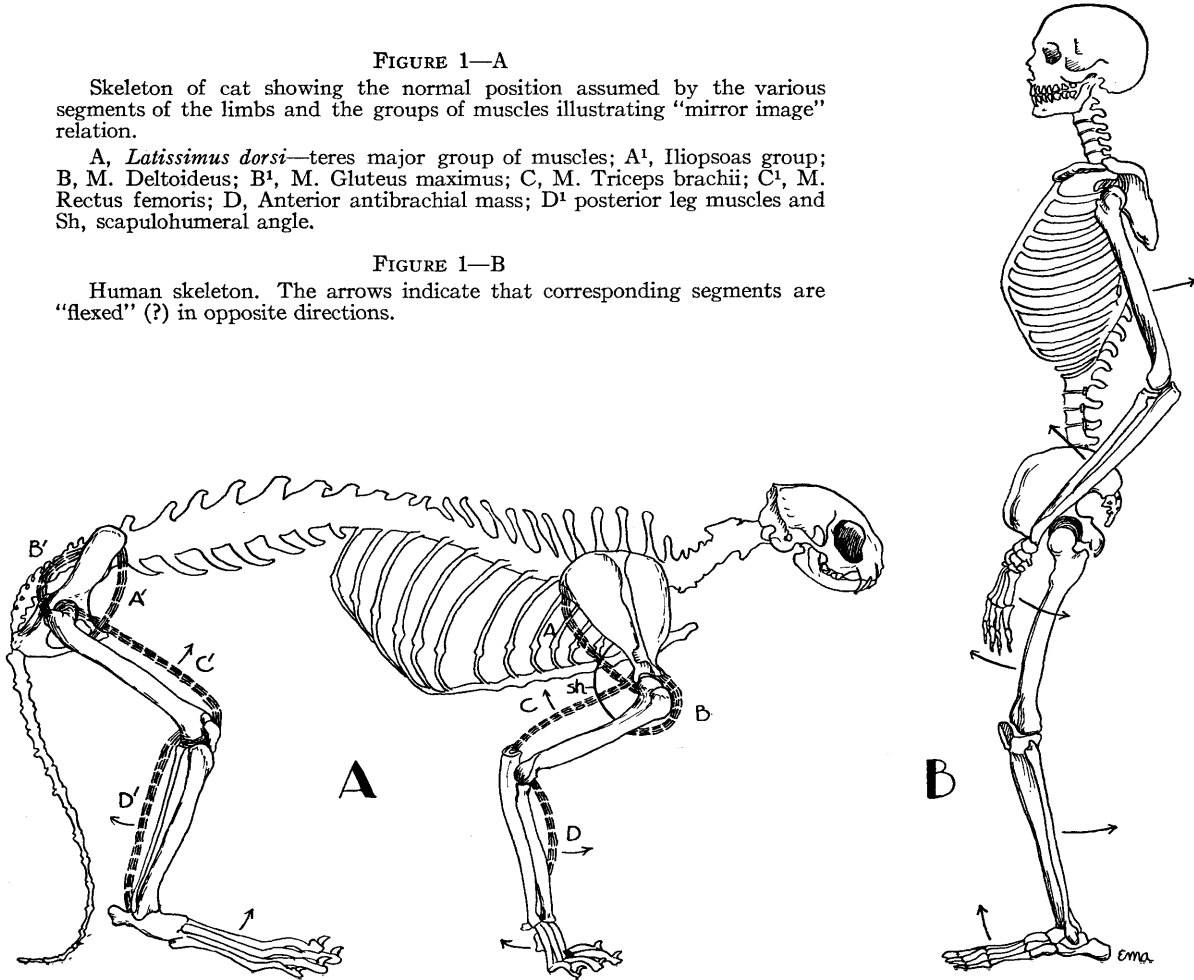
FIGURE 1—A

Skeleton of cat showing the normal position assumed by the various segments of the limbs and the groups of muscles illustrating "mirror image" relation.

A, *Latissimus dorsi*—teres major group of muscles; A<sup>1</sup>, Iliopsoas group; B, M. Deltoides; B<sup>1</sup>, M. Gluteus maximus; C, M. Triceps brachii; C<sup>1</sup>, M. Rectus femoris; D, Anterior antibrachial mass; D<sup>1</sup> posterior leg muscles and Sh, scapulohumeral angle.

FIGURE 1—B

Human skeleton. The arrows indicate that corresponding segments are "flexed" (?) in opposite directions.



of the scapula (figure 1A) so that flexion (swinging backward) of the humerus results in decreasing the scapulo-humeral angle, whereas extension (swinging forward) results in increasing this angle.

Diametrically opposed to this conception of flexion and extension of the shoulder-joint is the view adopted in the modern editions of most standard textbooks of Human (Gross) Anatomy. For example, in Quain's Anatomy, eleventh edition ('23), under the description of the action of the muscles which operate on the shoulder-joint (p. 115), appears this statement: "The movements of the arm, though difficult to classify, are best described by starting with the humerus in the hanging position. From this position it may be carried directly forwards to the horizontal plane—this movement is usually termed flexion—and then be elevated to the vertical position; oppositely it may be depressed to the hanging position, and then be carried backwards or extended."

Moreover, there is general agreement among human anatomists that the muscles involved in the production of flexion (swinging forward) of the humerus at the shoulder-joint are the coracobrachialis, the short head of the biceps brachii, the pectoralis major and the anterior fibers of the deltoid, whereas those involved in the production of extension (swinging backward) of the humerus are the latissimus dorsi, the teres major, the long head of the triceps brachii and the posterior fibers of the deltoid. In texts of Comparative and Veterinary Gross Anatomy, on the other hand, the flexor and extensor muscles of the quadruped shoulder-joint are classified as just the reverse of those in Human Anatomy.

In older editions of Human Anatomy texts the terms flexion and extension were not employed either in connection with the description of the shoulder-joint or with the muscles which act upon this joint. Apparently the issue was avoided by stating merely that the humerus "swings forward" and "backward" at the shoulder-joint and in the case of the muscles that they "draw the humerus forward" or "backward" as the case may be. However, in the older editions of Gray's Anatomy ('87) under the description of the triceps muscle it was stated that "when the arm is extended (sic) the long head of the triceps may assist the teres major and latissimus dorsi in drawing the humerus backward." It is evident, therefore, that in spite of the fact that these terms were not employed

in connection with the description of the movements of the shoulder-joint the implied meaning of the term "extension" of this joint was similar to that still in use in Comparative and Veterinary gross Anatomy. On the other hand, these terms were evidently employed in the same manner as used today before they were generally adopted in Human Anatomy textbooks as is evident by this statement of Wyman (1867): "If we admit the idea of symmetry in structure between arms and legs, and would compare the movements of the two in men and animals, we must change in some respects the terms flexion and extension, from those ordinarily used in the description of the human body. We will suppose the human skeleton suspended with the vertebral column horizontal, the limbs slightly flexed, the toes and fingers pointing downwards, the palms facing forwards and the soles backwards. Flexion of the humerus would be backwards, of the femur forwards." A review of the literature previous to as well as subsequent to the date of Wyman's paper has failed to cast any light on the question as to the explanation for the adoption of these terms as now used with reference to the human shoulder-joint.

Inasmuch as such a discrepancy exists between the various phases of anatomy with respect to the use and interpretation of the terms flexion and extension of the shoulder-joint, with the resulting confusion experienced by the student and much necessary explanation required on the part of the teacher in Human Anatomy, it occurred to the writer that some effort should be made to analyze the problem with the view to clarifying it or at least to arousing sufficient interest among human anatomists that some agreement eventually be arrived at relative to the terminology employed in connection with the human shoulder-joint. Aside from the academic aspect of the problem it is hoped that its solution would serve to enable the student to make a better adjustment between his courses in Comparative and Human Anatomy.

The objective aimed at in this paper is not to offer an explanation for, or to refute, the present concept of these terms prevailing in Human Anatomy but rather to raise certain questions bearing upon this concept. If, for example, flexion of the shoulder-joint in quadrupeds is regarded as swinging backward (caudad) of the humerus, whereas in biped man it is considered as swinging forward (craniad) can these divergent views be explained on the basis of man's assumption of an erect

posture, that is on the fact that man's pectoral limb was converted from an organ of progression or locomotion into one of prehension? If this explanation is tenable is swinging forward of the humerus of the child who is learning to "crawl on all fours" to be regarded as flexion or extension? Conversely which of these terms should be applied to swinging forward (craniad) of the humerus of those quadruped animals which are able temporarily to assume a biped mode of locomotion, such, for example, as the bear?

The characteristic attitude of the fetus is well known and the advantages of such a posture for conservation of space and for the presentation or passage of the fetus through the birth-canal are obvious. As regards this normal attitude, habitus or posture of the fetus is it true, as De Lee ('33) states and as is generally described, that it is one of flexion of all the joints? In this position the humerus of the child as well as that of most quadrupeds is displaced forward or craniad. Is the shoulder-joint of the human fetus to be regarded as in flexion, whereas, in the quadruped fetus it is to be considered as in extension?

Is it likely that the comparative anatomists are incorrect in their interpretation and that the conception of the human anatomists is the correct one? Or is it possible that the view adopted by the comparative anatomists is correct as regards quadrupeds but that this conception does not hold for biped man? If the comparative view-point is incorrect or, on the other hand, if it holds true only for quadrupeds then of what value is anatomical interpretation of the comparative anatomists to human anatomy in this instance? Or is it perhaps an unfortunate use of terminology employed by both Comparative and Gross Anatomists, that is, a matter of using physiological terms with a disregard to the true morphological relationship?

According to the comparative anatomists the fore and hind limbs of quadrupeds, or the superior and inferior extremities of man, are constructed on a common plan, each limb being divisible into three segments.

Wilder (1866) made the observation that "corresponding segments point and are flexed or extended in absolutely opposite though relatively similar directions." Thus, in the quadruped, as the cat for example, (fig. 1 A), the brachium extends ventrad and caudad, the antibrachium ventrad and slightly craniad and the manus is directed ventrad in alignment with the antibrachium with the palmar aspect facing caudad. In the

hind limb the thigh extends ventrad and craniad, the leg ventrad and caudad and the pes ventrad and craniad. In each limb, therefore, the segments are directed ventrad and craniad or ventrad and caudad so that corresponding segments in the two limbs extend in opposite directions. Moreover, flexion of the distal segments of the limbs involves, in the case of the forelimbs, bringing the palm of the manus toward the caudal or posterior aspect of the antibrachium (fig. 1 A) at the radiocarpal or wrist-joint, and in case of the hindlimb the anterior or cranial aspect of the pes toward the front of the leg at the ankle-joint; flexion of the antibrachium involves approximation of its anterior surface toward the anterior surface of the brachium at the elbow-joint and in the hindlimb flexion of the leg comprises approximation of its posterior surface toward the posterior surface of the thigh at the knee-joint. In the case of the proximal segment of the hind limb it is generally agreed that flexion of the thigh in both man and quadrupeds involves swinging its anterior aspect craniad at the hip-joint. If Wilder's statement be followed to its logical conclusion does it not follow, therefore, that flexion of the brachium would involve swinging its posterior or dorsal aspect caudad at the shoulder-joint, or in other words, decreasing the scapulo-humeral angle?

Does the position of the scapula and humerus of quadrupeds in comparison with those of man form a basis for an explanation of these divergent views? When we analyze the position of the scapula of quadrupeds, as for example the Carnivora, (fig. 1 A), we observe that it lies almost parallel with the median plane of the body, the glenoid fossa facing ventrad, the subscapular fossa mediad, the supraspinous and infraspinous fossae laterad and with its borders or margins directed craniad, caudad and dorsad, respectively. Correlated with the assumption of the upright posture of man was a change in the position of his scapula (fig. 1 B), which is situated on the dorso-lateral aspect of the thoracic wall. This shift backward (dorsad) of the scapula may be explained as resulting from a lateral expansion of the thorax, its transverse diameter having become relatively greater and its antero-posterior diameter relatively less. In man, therefore, the scapula is situated more nearly at right angles to the median plane of the body so that the glenoid fossa faces ventro-laterad, the subscapular fossa ventro-mediad and the supraspinous and infraspinous fossae dorso-laterad.

As regards the borders or margins the (original dorsal) medial or vertebral border lies on a plane almost at right angles to the spinous processes of the vertebrae rather than parallel with them as in quadrupeds; the (original anterior or cranial) superior border is still directed craniad and the (original caudal or posterior) axillary border still faces somewhat caudad but, as a result of the elongation inferiorly of the scapula and of its dorsal position, the latter border is directed ventro-laterad.

In quadrupeds the head of the humerus is situated on its dorsal aspect and, as a result of the position assumed by the humerus of a quadruped while standing or walking, it is directed dorso-caudad in apposition with the glenoid fossa which is directed ventro-craniad. As regards the position of the humerus in man it is well known that in the normal anatomic position of the human body it lies parallel with the longitudinal axis of the body, which in the human is vertical to the supporting surface as compared with quadrupeds in which it is parallel, so that the elbow-joint lies close to the side of the body. The dorsal and ventral (ventro-lateral and ventro-medial) surfaces of the humerus therefore face directly backward (dorsad) and forward (ventrad), respectively. Accompanying the change in the position of the humen scapula and the direction its glenoid fossa faces has been a corresponding change in the position of the head of the humerus which is directed dorso-mediad or almost entirely mediad. This shift in position of its head has been explained by numerous writers as the result of torsion which the bone has undergone. In spite of these evolutionary changes of the human scapula and humerus, including the fact that the transverse axis of the human shoulder-joint for swinging forward and backward has shifted somewhat due to the change in position of the head of the humerus and glenoid fossa of the scapula, does not the scapulo-humeral angle remain approximately the same as in quadrupeds (fig. 1, A and B)?

According to the theory of "mirror relation" as proposed by Parsons (1908) and Geddes (1912) there is a looking-glass symmetry or mirror image repetition of the girdles and segments of the limbs, that is the hind limb of either side is a mirror image of the fore limb of its own side just as it is a mirror image of the hind limb of the opposite side. Thus the caudal border of the scapula corresponds with the cranial border of the ilium, and the lesser trochanter of the femur with the lesser tuberosity of the humerus so that the teres major and subscapularis mus-

cles (fig. 1-A) correspond with the iliopsoas muscle ( $A^1$ ); the clavicle corresponds with the ischium, the gluteal tuberosity of the femur with the deltoid tuberosity of the humerus and the deltoid muscle (B) with the gluteus maximus ( $B^1$ ); the infraglenoid tuberosity of the scapula corresponds with the anterior inferior iliac spine, the olecranon process of the ulna with the patella and the triceps muscle (C) with the rectus femoris ( $C^1$ ); the coracoid process of the scapula corresponds with the pubis and the coracobrachialis muscle corresponds with the adductor magnus, et cetera.

On the basis of this theory, if followed to its logical conclusion, does it not appear reasonable that if the rectus femoris muscle extends the leg at the knee-joint and flexes the thigh at the hip-joint that the corresponding muscle, namely the triceps, which extends the antibrachium at the elbow-joint, would therefore flex, that is draw backward or caudad, the brachium at the shoulder-joint? Similarly if the iliopsoas muscle flexes the hip-joint would not the subscapularis—teres major group, therefore, flex the shoulder-joint?

In conclusion, the question naturally arises as to which of these opposing views conforms to the true morphological or embryological history of the limbs. A brief review of the stages through which the vertebrate limbs pass in their phylogenetic and ontogenetic development brings out the following: when the limbs first make their appearance their longitudinal axes lie parallel with the longitudinal axis of the body and are directed caudad, the ulna and fifth finger looking dorsad and the palmar and plantar surfaces of the manus and pes facing mediad (fig. 2A). In many Mammalia a secondary modification occurs in which the limbs are extended at right angles to the body and lie parallel to each other. In this position each limb presents a dorsal and ventral surface and an anterior or preaxial and a posterior or postaxial border. The dorsal surface of the forelimb, or superior extremity of man, includes the back of the manus and the so-called extensor surface of the antibrachium and brachium while the dorsal surface of the hindlimb, or inferior extremity, includes the dorsum of the pes, the front of the leg and the extensor surface of the thigh. The preaxial border of the forelimb comprises the pollex, radius, lateral (external) condyle and greater tuberosity whereas that of the hindlimb comprises the hallux, tibia, medial (internal) condyle of the femur and the lesser trochanter.



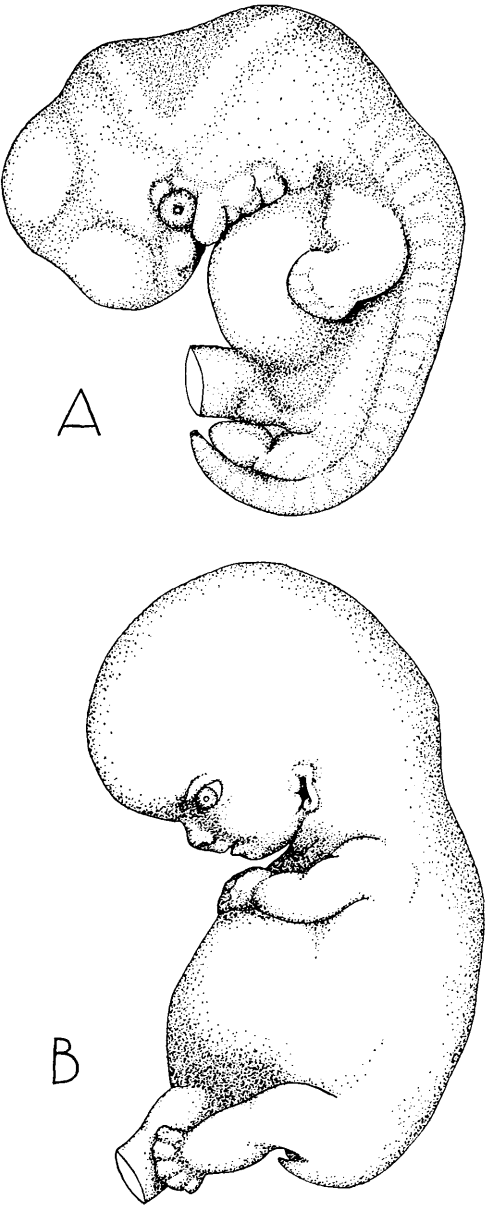


Fig. 2. Human embryos showing position of limbs at A, 31-34 days (11 mm.) and B, 42-45 days (16 mm.), after His.

In a later stage of development the distal extremities of the limbs are directed ventrad, with their longitudinal axes still at right angles to that of the body, the palmar surface of the manus and the plantar surface of the pes face mediad, while the elbow points caudad and the knee craniad (fig. 2B). The next stage is characterized by rotation of the limbs around their longitudinal axes through an angle of 90 degrees, the direction of rotation of the fore and hindlimbs being reversed. Thus the forelimb is rotated laterad with the result that the preaxial border is directed laterad, and the ventral surface faces craniad; the hindlimb is rotated mediad so that its preaxial border is directed mediad, its (original) ventral surface faces caudad and the hallux lies on the inner or medial border of the pes. Finally, in nearly all terrestrial mammals the antibrachium is rotated mediad or pronated so that the manus swings round from the back to the front of the limb with the distal end of the radius overlapping the ulna in which position it remains fixed in most quadrupeds. In the so-called normal anatomic position of man, however, the body is erect and the fore limb or superior extremity is pendant with the palmar aspect of the manus facing ventrad and the preaxial border, that is the pollex, the radius and the lateral border of the humerus, is directed laterad.

#### CONCLUSIONS

It is generally concluded, therefore, that the hallux is homologous with the pollex, the palmar surface of the manus with the plantar surface of the pes, the tibia with the radius, the knee with the elbow, the ventral or anterior (original dorsal) surface of the leg and thigh with the (original) dorsal or posterior aspect of the antibrachium and brachium and so on. Furthermore, in the light of these conclusions, it is evident that the dorsal musculature of the brachium, that is the triceps complex which extends the antibrachium at the elbow, corresponds with the ventral (original dorsal) musculature of the thigh which extends the leg at the knee; the dorsal antibrachial musculature, which extends the manus and fingers, corresponds with the ventral (original dorsal) musculature of the leg which, however, is said to flex (dorsi-flex) the pes and to extend the toes. As regards the latter discrepancy as well as the action of the dorsal and ventral musculature of the thigh and brachium at the hip- and shoulder-joints, respectively, in the light of

their true morphological relationships what conclusions could be reached?

McMurrich ('23), in discussing this problem, remarked (p. 106) that "It may be pointed out that the prevalent use of the physiological terms flexor and extensor to describe the surfaces of the limbs has a tendency to obscure their true morphological relationships. Thus, if, as is usual, the dorsal surface of the arm be termed its extensor surface, then the same term should be applied to the entire ventral surface of the leg, and all movements of the lower limb ventrally should be spoken of as movements of extension and any movement dorsally as movements of flexion. And yet a ventral movement of the thigh is generally spoken of as a flexion of the hip-joint, while a straightening out of the foot upon the leg—that is to say, a movement of it dorsally—is termed its extension."

If the (original) dorsal musculature of the limbs is to be considered an extensor group and the (original) ventral musculature a flexor group, as is generally held by the majority of morphologists, does it not follow, therefore, in the light of this interpretation, that swinging forward (that is ventrad in the human or craniad in quadrupeds) of the humerus should rightly be termed flexion whereas swinging forward of the femur should in reality be called extension; that bringing the palm toward the ventral aspect of the antibrachium is correctly named flexion, whereas displacement of the sole toward the posterior (original ventral) aspect of the leg, as in "standing on tip-toes" should really be termed flexion rather than extension?

Indeed the whole subject of the action of the musculature of the limbs is badly in need of revision and, insasmuch as the present paper is largely analytical and more or less subjective, the writer recommends that the question be thoroughly reconsidered with the view to clarifying the existing confusion.

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